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POSITION SENSING BY CHARGE DIVISION USING SELF QUENCHING STREAMER PULSES

M. Atac and F. Bedeschi
Fermi National Accelerator Laboratory*
Batavia, IL 60510

Introduction

Position sensing along an anode wire in proportional or drift chambers by charge division has been used in high energy physics experimentation[1-3], however, due to the requirements of sophisticated electronics for obtaining a satisfactory positional accuracy, the usage of it has been limited. In this paper, we show that very good position resolutions can be obtained by the charge division method using simple electronics and self quenching streamer pulses.[4]

Experimental Arrangement

Extruded aluminum tubes of 2 m long, 2 cm x 2 cm size were used for simplicity and convenience as drift tubes. The anode wires were 50 μm and 75 μm thick stainless steel alloy with a resistivity of 440 and 240 ohms, respectively. The wire was applied positive high voltage, and the pulses were picked up through 0.1 μf capacitors. 50 percent A - 50 percent C_2H_6 mixture bubbled through ethyl alcohol at 0° C was the gas mixture.

As shown in Fig. 1 that the wire signals from each end was directly injected into a commercial ADC (LeCroy 2285). The gain of the ADC was 20 counts/pc. The resistors, R_T collect a small fraction of the streamer signal for generating a trigger pulse. The data was stored and on-line displayed via a PDP 11/20 computer using MULTI[5] acquisition system.

Due to lack of high energy particle beam at Fermilab during this period and for simplicity, an Fe^{55} source was positioned on some predrilled holes for the following measurements. The size of the collimated 5.9 keV x-ray source was 1 mm. Most of the data presented here was obtained from the 50 μm wire; we will also show some results from the 75 μm wire. The total length of the wires was 200 cm.

Some definitions:

Q_1 = charge measured in ADC1

Q_2 = charge measured in ADC2

$f = (Q_1 - Q_2)/(Q_1 + Q_2)$

Assuming ideal charge division,

$$f = \frac{\alpha}{1 + \frac{2R}{R_W}}$$

where $\alpha = \frac{2x}{\ell}$, $(-\frac{\ell}{2} < x < \frac{\ell}{2})$ and R = impedance seen at each end by the wire.

Results

Fig. 2 shows the measured resolution as a function of the source position. It includes the finite width (1 mm) of the source, nonuniformity of the wire, and the pedestal noise of the ADC's. This folded resolution ranges from 1 mm to 1.4 mm, and the shape of the measured distribution is quite Gaussian (Fig. 3).

Assuming that the precision of our measurement is due only to the precision of measuring the charge, the standard error expansion gives:

$$\sigma = \left\{\left[\sigma_1^2 + 2c\,\sigma_1\sigma_2 + \sigma_2^2\right)f^2 + 2(\sigma_1^2 - \sigma_2^2)f + (\sigma_1^2 - 2c\,\sigma_1\sigma_2 + \sigma_2^2)\right]/Q_o^2 + \sigma_{coll}^2\right\}^{1/2}$$

Where σ_1 = error on Q_1

σ_2 = error on Q_2

c = correlation coefficient

σ_{coll} = source collimation spread

$Q_o = Q_1 + Q_2$ (collected charge)

This expression was compared with our data. σ_f versus charge, Q_o is shown in Fig. 4a and b, when the source was kept at the center and at the end, respectively. Agreement between the data and the predicted courve is excellent. The curves in Figs. 4a and b are consistent with $\sigma_1 = \sigma_2 = 50$ fc (1 ADC count) and $\sigma_{coll} = 0.5$ mm. There is a small but consistent bump around 90 pC charge value. This value corresponds to pulse height region (Fig. 5) where both double and single streamers occur thus causing a spread in the σ_f.

Using the σ_{coll} value previously determined σ_f versus f expression was fitted to our data for two values of the charge as shown in Fig. 2. Both fits are in good agreement with the data. This is consistent with c = 0.25 and $\sigma_1 = \sigma_2 = 1$ ADC count which is typical value of the pedestal distribution spread obtained when triggering with a pulser.

From these results we conclude that the inherent resolution is better than what is shown here and is mainly limited by the ADC pedestal noise.

Linearity

The f value was plotted against the measured source position. Fig. 6 shows the residuals after the linear fit to this plot.

It appears that our data is consistent with a different slope on either side of the center. With this fit, the deviations appear to be within ± 0.2 mm which is our precision of measuring hole positions.

240 Ω Wire

We found no significant change in resolution when using wire (240 Ω/m), Fig. 7. This is due to the fact that additional charge obtained from thicker wire compensated expected worsening of the resolution. In this case, c was found to be 0.75.

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Some Observations

We found that the resolution is strongly correlated with the value of $t = (2R + R_W)C$ as it was pointed out elsewhere[1]. This effect is clearly observable as an offset in values as correlated to Q_O when the blocking capacitors have a value of 0.005 μf (instead of 0.1 μf used for obtaining the above results). This is seen in Fig. 8 as a correlation scatterplot. The following is noticeable:

1. The f value is reduced.
2. Two bands appear; one for the single streamer pulses and another one for the doubles.
3. Each band has a very noticeable slope.
4. All these effects are greatly improved around the midpoint of the wire.

The effect on the resolution is seen as larger σ_f than expected toward the end of the wire. This reflects into the previous fit as a larger correlation coefficient.

Conclusions

We are convinced that few hundred microns of resolutions may be obtainable using more sensitive ADC's with less pedestal noise and beam particles.

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References

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Ref. 2 V. Radeka and P. Rehak, IEEE Trans. Nucl. Sci., Vol. 25 (1978) 46.

Ref. 3 M. Matoba, K. Tsuji, K. Marubayashi, and T. Shintake, Nucl. Instr. and Meth. 165 (1979) 469.

Ref. 4 M. Atac, D. Potter, and A. Tollestrup, Fermilab Internal Report FN-339 (July 1981) To be published in Nucl. Instr. and Meth.

Ref. 5 F. Bartlett, L. Taff, D. Ritchie, and T. Lagerlund, Fermilab Internal Report.

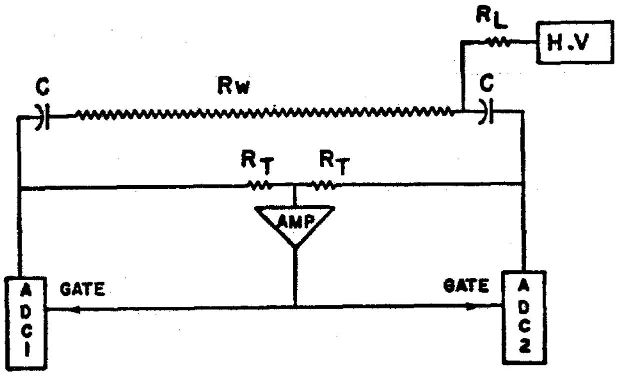

Fig. 1 Experimental setup.

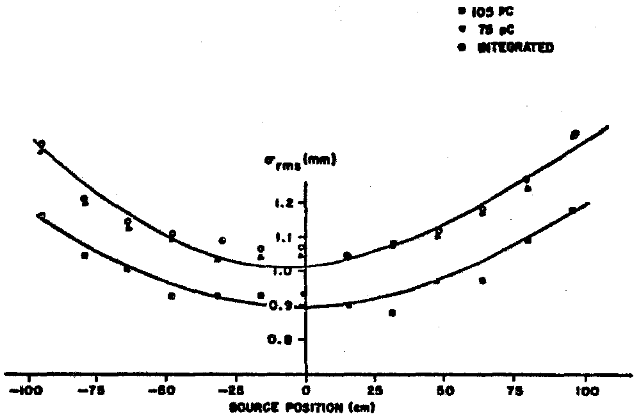

Fig. 2 Resolution as a function of source position for R = 440 Ω/m. Solid lines are fits to given constant charge data.

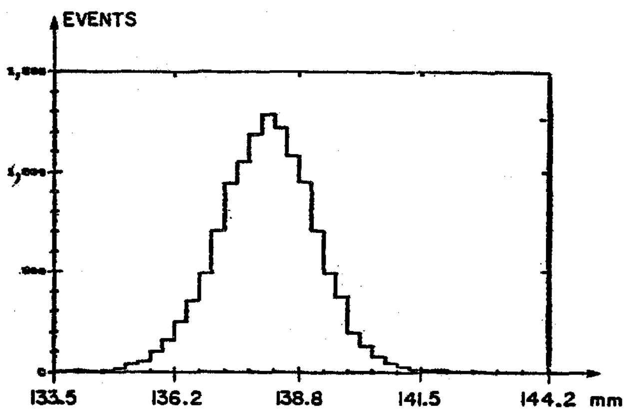

Fig. 3 Typical resolution distribution.

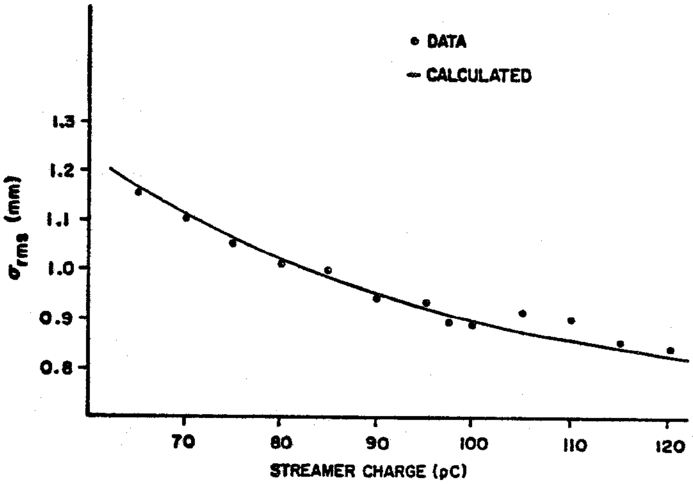

Fig. 4a   Resolution as a function of streamer charge at the middle.

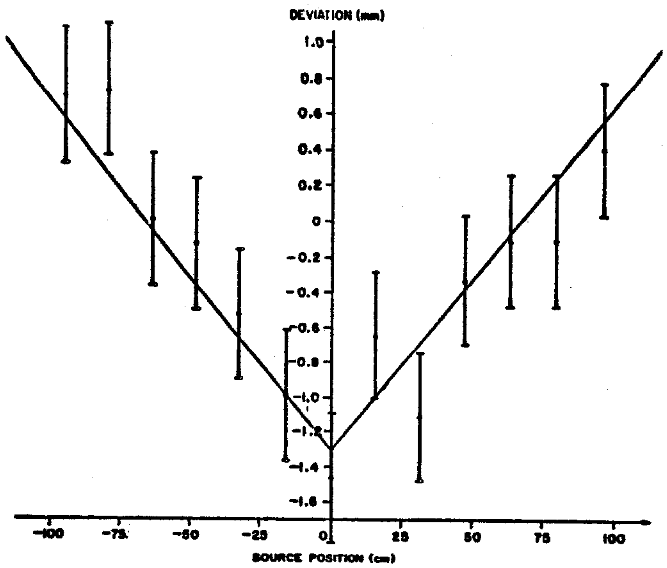

Fig. 6   Residuals as a function of source position.

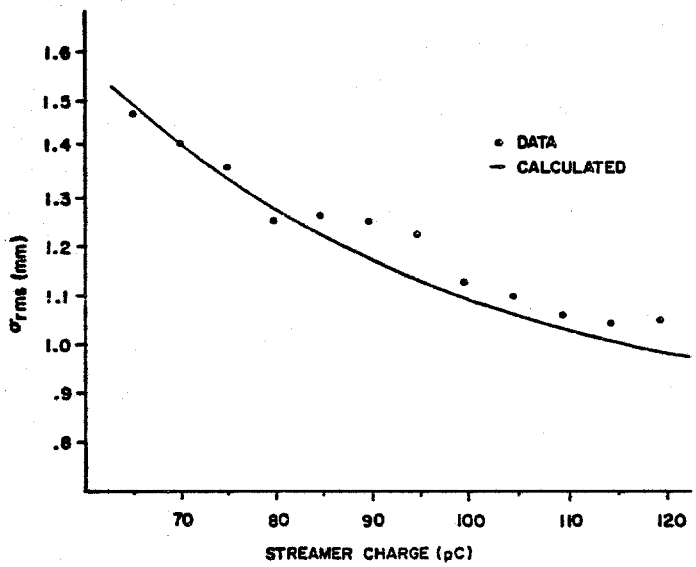

Fig. 4b   Resolution as a function of streamer charge at one end.

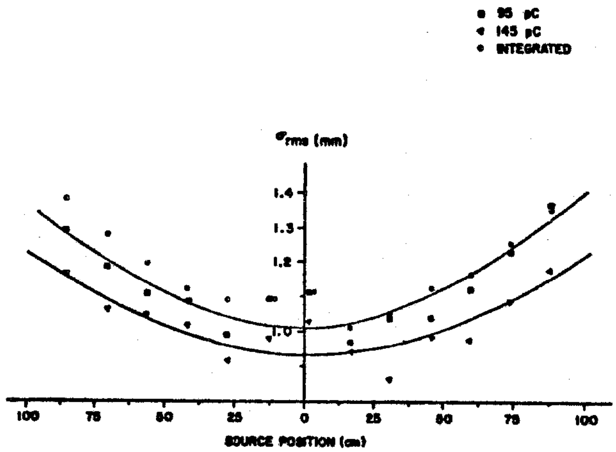

Fig. 7   Resolution as a function of source position for R = 240 Ω/m. Solid lines are fits to given constant charge data.

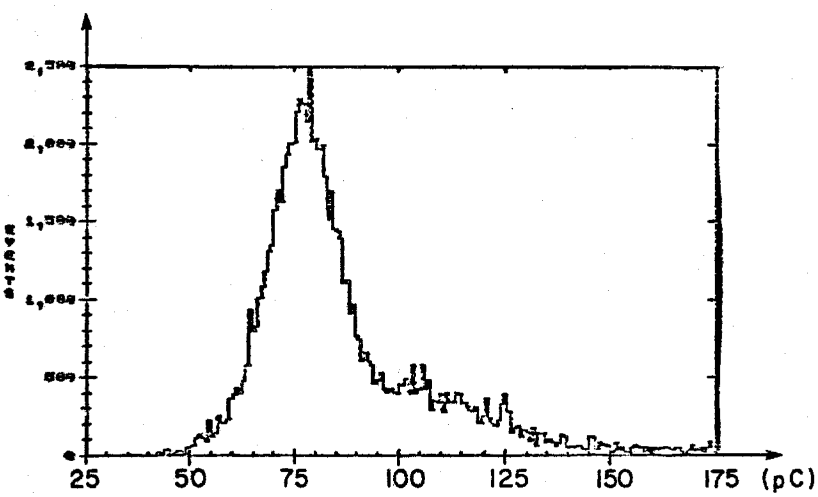

Fig. 5   Total charge distribution.

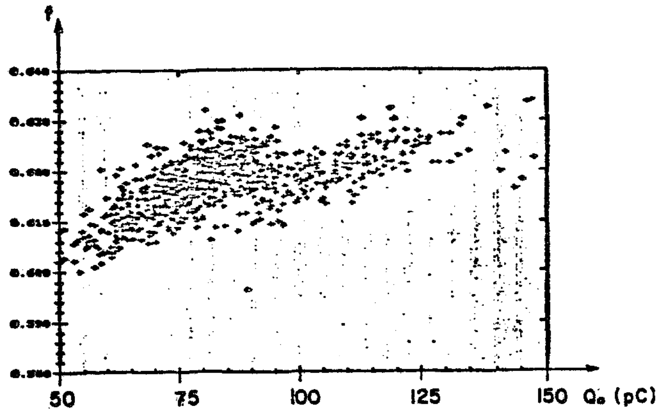

Fig. 8a Correlation between f and Q_o for C = 0.005 μf.

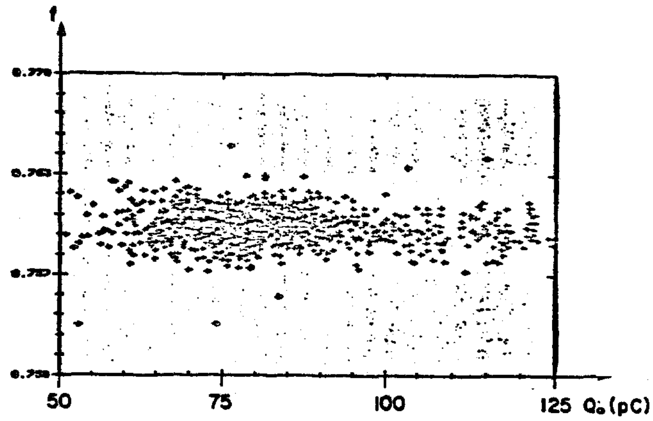

Fig. 8b Correlation between f and Q_o for C = 0.1 μf.